Potassium, calcium and magnesium in tropical ornamental plants micropropagation [1]

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ABSTRACT

Considering the increase in economical importance of species belong to Zingiberaceae family for floriculture and the advantages of techniques applied to micropropagation of these plants, it is necessary to carry out studies about growth of species in these conditions. The aim of this study was to evaluate the *in vitro* development of *Etlingera elatior*, *Zingiber spectabile* and *Alpinia purpurata* under different ratios of K, Ca and Mg. The treatments were based on MS medium with K: Mg ratios (mmol L^{-1}) of: 22K:1Mg, 20K:3Mg, 16K:7Mg, 12K:11Mg, 8K:15Mg 4K:19Mg; K:Ca ratios (mmol L^{-1}) of: 22K:4Ca, 20K:6Ca, 16K:10Ca, 12K:14Ca, 8K:16Ca and 4K:22Ca; with five replications, and two seedlings per pot. Explants used were obtained from *in vitro* rhizomes, kept in a room at a temperature of 25 ± 2°C under irradiance 52W m^{-2} s^{-1} and 16 hours photoperiod. After 80 days, seedlings were harvest and have the about number of leaves, height and length of root measured. After, seedlings were separated in shoots and roots, dried and carried out chemical analysis of plant tissue. It is possible to improve the Zingiberaceae plants growth during the micropropagation, changing the concentrations of original formulation MS medium. For K are recommended concentrations of 22 mmol L^{-1} to *Etlingera elatior* and *Zingiber spectabile* cultivation and 16 mmol L^{-1} for *Alpinia purpurata.* For Ca, we recommend the concentrations of 4 mmol L^{-1} for *Etlingera elatior* and *Zingiber spectabile* and from 8 to 10 mmol L^{-1} for *Alpinia purpurata*. A higher concentration of Mg for *in vitro* cultivation *Etlingera elatior* is required. For *Zingiber spectabile* and *Alpinia purpurata* it was recommended the proposed merger among MS original concentration of 3 mmol L^{-1} of this macronutrient.

Keywords: Tissue culture, *in vitro,* mineral nutrition, Zingiberaceae.

RESUMO

Potássio, cálcio e magnésio na micropropagação de plantas tropicais ornamentais

Considerando a crescente importância econômica de espécies da família Zingiberaceae para a floricultura e as vantagens das técnicas aplicadas ao cultivo *in vitro* para estas plantas, torna-se necessária a realização de estudos que avaliem o crescimento das espécies desta família nestas condições. Diante do exposto, o objetivo do trabalho foi avaliar o desenvolvimento *in vitro* de espécies *Etlingera elatior*, *Zingiber spectabile* e *Alpinia purpurata* em função de diferentes relações de K, Ca e Mg. Os tratamentos foram baseados no meio MS básico com relações K:Mg (mmol L^{-1}) de: 22K:1Mg, 20K:3Mg, 16K:7Mg, 12K:11Mg, 8K:15Mg e 4K:19Mg; relações K:Ca (mmol L^{-1}) de: 22K:4Ca, 20K:6Ca, 16K:10Ca, 12K:14Ca, 8K:16Ca e 4K:22Ca, com cinco repetições, sendo a parcela experimental composta de duas plântulas por frasco. Foram utilizados como explantes rizomas de plântulas *in vitro*, mantidas em sala de crescimento, a temperatura de 25±2 °C, sob irradiância 52 W m^{-2} s^{-1} e fotoperíodo de 16 horas. Após 80 dias de cultivo, as plântulas foram avaliadas em relação às variáveis: número de folhas, altura e comprimento da raiz. Posteriormente, foram determinadas as massas secas da parte área e raiz, relação parte aérea/raiz e realizada a análise química das folhas. Foi possível melhorar o crescimento das plantas de zingiberáceas avaliadas, na fase de micropropagação, mudando-se as concentrações de K, Ca e Mg da formulação original do meio MS, sendo recomendadas as concentrações de K de 22 mmol L^{-1} para *Etlingera elatior* e *Zingiber spectabile* e de 16 mmol L^{-1} para *Alpinia purpurata* e concentração de Ca de 4 mmol L^{-1} para *Etlingera elatior* e *Zingiber spectabile,* e entre 8 a 10 mmol L^{-1} para *Alpinia purpurata*. Uma maior concentração de Mg para o cultivo *in vitro* de *Etlingera elatior* é necessário. Para *Zingiber spectabile* e *Alpinia purpurata* são recomendadas a concentração proposta no meio MS de 3 mmol L^{-1} de Mg.

Palavras-chave: Cultura de tecidos, *in vitro,* nutrição mineral, Zingiberaceae.

1. INTRODUCTION

Tropical flowers, classified as a lucrative business, has been expanding and being considered a viable alternative to small rural areas. Brazil has the potential to become great emphasis on the production of tropical flowers and ornamental plants, mainly due to the favorable climate for its production (JUNQUEIRA and PEETZ, 2011).

The species *Etlingera elatior* (torch ginger), *Zingiber spectabile* (ornamental ginger) and *Alpinia purpurata* belong to Zingiberales order and Zingiberaceae family, originating in Asia (LAMB et al., 2013). The species of this family have favorable characteristics for trade as cut flowers, with atypical shapes and vibrant colors of the flowers of these plants (LOGES et al., 2008).

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The cultivation of these species seedling production is carried out vegetatively through rhizomes. However, this practice can lead to disease problems, including the spread of disease, leading to the total destruction of crops due to rapid spread, mainly fungi and bacteria (DEBIASI et al., 2004).

Micropropagation has allowed commercial production of disease free plants, allowing the multiplication of promising materials in periods of time and reduced space. Furthermore, this spreading technique maintains the identity of the propagated genetic materials (FUZITANI and NOMURA, 2004). The MS medium (MURASHIGE and SKOOG, 1962) is one of the most used for the propagation of various plant species, including ornamentals. The concentration of MS medium nutrients is high, and in this sense, changes have been suggested, aiming to greater performance and cost reduction (MOREIRA et al., 2012).

In addition to adequate amounts of nutrients to the full development of seedlings, it is also necessary to occur the balance between them. The presence of a given nutrient availability may change and affect the nutritional balance of another (FURTINI NETO et al., 2001). Thus, studies are conducted to verify the development of different species with respect to growth and mineral nutrition in micropropagation. However, few studies on nutritional balance involving ornamentals, specifically the Zingiberaceae are found. Therefore, the objective of this study was to evaluate the *in vitro* development of species of Zingiberaceae family (*Etlingera elatior*, *Zingiber spectabile* and *Alpinia purpurata*) for different relations between K, Ca and Mg.

2. MATERIAL AND METHODS

Plants for *in vitro* cultivation were provided by the unit of the Brazilian Agricultural Research and - Tropical Agroindustry (EMBRAPA), located in Fortaleza, Ceará.

The seedlings *Etlingera elatior* (porcelain variety), *Alpinia purpurata* and *Zingiber spectabile* were subcultured under aseptic conditions in culture MS medium (MURASHIGE and SKOOG, 1962) plus 2.5 mg L^{-1} of 6-benzilamonopurina (BAP) and solidified with agar at a concentration of 5.5 g L^{-1}.

Rhizome segments (explants) with approximately 0.5 cm were removed from these plantlets was inoculated in different ratios K: Mg and K: Ca. The treatments were based on the basic medium MS (MURASHIGE and SKOOG, 1962) with K: Mg ratios (mmol L^{-1}) of: 22K: 1mg, 20K: 3mg, 16K: 7mg, 12K: 11mg, 8K: 15mg and 4K: 19mg, and relationships K: Ca (mmol L^{-1}) of: 22K: 4Ca, 20K: 6Ca, 16K: 10Ca, 12K: 14Ca, 8K: 16Ca and 4K: 22Ca. The concentrations of 20 mmol L^{-1} to K, 6 mmol L^{-1} for Ca and 3 mmol L^{-1} for Mg are recommended by Murashige and Skoog (1962) and considered as a standard. The ionic balance nitrogen was performed with the use of ammonium nitrate. The explants were maintained throughout the experimental period in the growth room at 25 ± 2°C under irradiance 52 W m^{-2} s^{-1} and a photoperiod of 16 hours. The experimental design was completely randomized and the experimental portion composed of two explants per bottle, with five repetitions.

After 80 days, the seedlings were evaluated for the following growth variables: height, leaf number and root length. To this end, the plantlets were removed from the flasks, washed in distilled water and the plant material packaged in paper bags and maintained in an oven with forced air circulation at 65°C to constant weight. After the determination of dry weight of shoot and root, milling of each part of the plant material in Willey mill with a sieve of 20 mesh for determination of mineral composition was performed according to the methodology described by Malavolta et al. (1997). The shoot ratio: root (PA/Root) was calculated by dividing the dry weight of shoot the root dry mass.

The data were submitted to analysis of variance and means were compared by Tukey test at 5% probability. Statistical analysis was performed using Minitab software 17 (MINITAB 17 STATISTICAL SOFTWARE, 2014).

3. RESULTS AND DISCUSSION

Growth and nutritional content of the shoot in zingiberaceas seedlings under different K:Mg

The *Etlingera elatior* seedlings in 20K treatment: 3Mg showed an increase in the number of leaves, while there was a decrease in this parameter in 16K treatment of seedlings: 7 mg (Table 1). The height and shoot dry weight were not influenced by the different relations K: Mg.

Table 1. Growth, dry matter production and relationship PA/root *Etlingera elatior*, *Zingiber spectabile* and *Alpinia purpurata* subjected to culture medium with different relationships K: Mg (mmol L^{-1}).
Tabela 1. Crescimento, produção de massa seca e relação PA/Raiz de Etlingera elatior, Zingiber spectabile e Alpinia purpurata submetidas a meio de cultura com diferentes relações K:Mg (mmol L^{-1}).

Relation K:Mg	Number of leaves	Height	Root length (RL)	Dry mass		Relation RL/Root
				Aerial part	Root	
		----------cm----------		----------g----------		
Etlingera elatior						
22:1	5.5ab	9.8a	10.8b	0.14a	0.009c	16.0a
20:3	6.3a	11.2a	9.4b	0.18a	0.014bc	14.1a
16:7	4.4b	10.2a	20.5a	0.12a	0.030abc	4.7b
12:11	5.4ab	13.5a	19.2a	0.14a	0.030abc	5.2b
8:15	5.6ab	12.1a	18.2a	0.15a	0.038ab	4.2b
4:19	5.3ab	11.3a	15.8ab	0.14a	0.049a	3.1b
Zingiber spectabile						
22:1	7.5a	5.9b	3.8a	0.09b	0.060b	1.5a
20:3	7.1ab	8.8a	6.5a	0.15a	0.092ab	1.7a
16:7	5.1b	6.1ab	5.2a	0.06b	0.040b	1.7a
12:11	5.9ab	7.4ab	7.3a	0.10b	0.084ab	1.2a
8:15	5.9ab	7.2ab	7.4a	0.10b	0.084ab	1.0a
4:19	6.8ab	6.2ab	6.5a	0.11ab	0.115a	1.2a
Alpinia purpurata						
22:1	6.4a	6.6b	3.4bc	0.17a	-	-
20:3	10.9a	6.2b	2.6c	0.17a	-	-
16:7	8.9a	8.7a	10.1a	0.18a	-	-
12:11	7.8a	6.8b	5.5b	0.17a	-	-
8:15	9.0a	5.9b	3.4bc	0.17a	-	-
4:19	9.0a	5.6b	2.3c	0.23a	-	-

Means followed by the same letter in the columns do not differ by Tukey test at 5% probability.

During the experimental period were not detected K and Mg deficiency symptoms in the aerial part of *Etlingera elatior* in any treatment. The root system of the seedlings grown under the relations of 22K:20K and 1.0 mg: 3Mg visually showed less development. The largest production of dry mass of root was found in seedlings treatment 4K: 19mg, while the lowest was observed in seedling treatment 22K: 1 mg.

Drew (1975) studied the growth of barley plants growing in solution with low concentrations of K found that root growth of plants such treatment was similar to the control. Although low concentrations of K in the culture medium, they were enough to root development of seedlings.

The *Etlingera elatior* seedlings 22K of treatment: 1.0 mg and 20K: 3Mg showed higher shoot/root (PA/Root), indicating the lower development of the aerial part of these seedlings when compared with other treatments. The lower concentration of Mg in the culture medium resulted in lower development of the aerial part, since the nutritional deficiency of magnesium can affect plant development.

Cakmak and Yazici (2010) found that deficient bean plants Mg decreased growth in shoot and roots. According to Bergmann (1992), low plant development is nutritional deficiency symptoms in general, including Mg.

Number of leaves, the seedlings of *Zingiber spectabile* 22K of treatment: 1.0 mg showed the largest increase, while the 16K treatment plants: 7mg decreased this variable (Table 1). In the dry height and weight of shoots, the plants of 20K: 3Mg showed the largest increase in that variable. Among the treatments studied, there were no significant differences in root length and ratio PA/Root. For dry root mass, the treatment plans 4K: 19mg showed the highest values, as well as seedling *Etlingera elatior*.

Seedlings of *Alpinia purpurata* of the treatments did not differ in the number of leaves and dry weight of shoot (Table 1). For height and length of the root seedlings of 16K treatment: 7.0mg showed an increase in these variables.

Paula et al. (2015) evaluating the K:Mg ratios in three banana cultivars, noted that hick cultivars and Tropical achieved the best results in the growth of shoots and roots in 20K treatment: 3Mg, while the seedlings of the plantain (*Musa* spp. var. Japira) have developed better in relation 22K: 1.0 mg. The three species of this study showed different behaviors in K:Mg ratios.

No differences were observed in the levels of Ca and P for *Etlingera elatior* seedlings, the K and S contents of *Zingiber spectabile* and P contents of *Alpinia purpurata* subjected to the culture with different ratios K: Mg (Table 2).

Table 2. Levels of macronutrients (g kg^{-1}) sheets of *Etlingera elatior* seedlings, *Zingiber spectabile* and *Alpinia purpurata* with different ratios K:Mg (mmol L^{-1}).
Tabela 2. Teores de macronutrientes (g kg^{-1}) em folhas de plântulas de Etlingera elatior. Zingiber spectabile e Alpinia purpurata com diferentes relações K:Mg (mmol L^{-1}).

Relation K:Mg	P	K	Ca	Mg	S
	g kg^{-1}				
Relation K:Mg					
Etlingera elatior					
22:1	4.06a	35.45a	5.83a	0.93d	0.82b
20:3	3.04a	36.15a	5.54a	1.48c	0.86b
16:7	3.75a	36.11a	6.25a	3.14b	1.07a
12:11	3.53a	37.19a	5.84a	4.33b	1.18a
8:15	2.87a	28.82b	5.41a	6.42ab	1.51a
4:19	4.55a	25.79b	5.83a	7.91a	1.74a
Zingiber spectabile					
22:1	3.8ab	35.7a	13.5a	2.1de	1.4a
20:3	2.9b	35.5a	7.4b	1.1e	0.7a
16:7	2.1b	36.7a	6.8b	3.7d	0.6a
12:11	3.1b	33.8a	5.4b	5.3c	0.6a
8:15	3.1b	32.6a	4.5b	7.1b	0.7a
4:19	4.7a	31.8a	4.7b	10.2a	0.9a
Alpinia purpurata					
22:1	2.97a	22.66a	1.75a	0.98d	3.67e
20:3	2.93a	25.62a	1.63a	1.27cd	4.71d
16:7	2.95a	22.66a	2.65a	3.45b	3.66e
12:11	2.75a	25.36a	1.97a	2.88c	5.43c
8:15	2.60a	25.16a	1.44a	3.30b	6.15b
4:19	2.72a	12.77b	0.80b	4.39a	9.53a

Means followed by the same letter in the columns do not differ by Tukey test at 5% probability.

The culture medium with 4K ratio: 19.0 mg enabled higher P uptake by seedlings of *Zingiber spectabile*. The high Mg content in the culture medium favored the absorption of P, as is synergism between these ions (FAGERIA, 2001). It is believed that the interaction between P and Mg are related to energy transfer reactions in the cell (BERGMANN, 1992), such as the activity of kinases and enzymes in phosphate transfer reactions (FAGERIA, 2001).

The lower K levels were observed in *Etlingera elatior* seedlings and *Alpinia purpurata* treatments with lower concentrations of K in culture media (8K: 15.0 mg and 4K: 19.0 mg). There was an increase in Mg with increasing its concentration in the culture medium for all species.

The first condition for the ion to be absorbed is that should be available in shape and be in contact with the root surface. Thus, in lowest concentration of that ion in the culture medium, lowest absorption will occur by the plants (FAQUIN, 2005).

The highest Ca concentrations were observed in seedlings of 22K treatment: 1.0 mg to *Zingiber spectabile* (Table 2). It can be seen that the lower Mg concentration in the culture medium favored the absorption of Ca in the mineral nutrition of the plants, this fact is related to their very similar chemical properties, as valence and the degree of mobility, so that there competition for the adsorption sites in the soil and root uptake. As a result, an excessive presence may hinder the absorption of other (ORLANDO FILHO et al., 1996).

An increase in S content of the seedlings of *Zingiber spectabile* and *Alpinia purpurata* as it decreased the increased K and Mg in the culture medium. They are not reported in the literature specific interactions between these nutrients and S.

Growth and nutritional content of the shoot in zingiberaceas seedlings under different relations K:Ca

The ratio of 20K: 6Ca caused a reduction in the number of leaves and height of the seedlings *Etlingera elatior* (Table 3). To root length, plantlets treatment 4K: 22Ca were inferior. The dry mass of root was not affected by different relations of K: Ca.

Table 3. Growth variables, dry matter production and relationship PA/root *Etlingera elatior*, *Zingiber spectabile* and *Alpinia purpurata* subjected to culture medium with different relationships K:Ca (mmol L^{-1}).
Tabela 3. Variáveis de crescimento, produção de massa seca e relação PA/Raiz de Etlingera elatior, Zingiber spectabile e Alpinia purpurata submetidas a meio de cultura com diferentes relações K:Ca (mmol L^{-1}).

Relation K:Ca						
Etlingera elatior						
Relation K:Mg	Number of leaves	Height	Root length (RL)	Dry mass		Relation RL/Root
				Aerial part	Root	
		----------cm----------		----------g----------		
22:4	6.1a	11.2a	15.2ab	0.21a	0.022a	9.8ab
20:6	3.8b	7.6b	11.5ab	0.13a	0.038a	3.3b
16:10	5.6a	12.0a	18.1a	0.16a	0.041a	4.3b
12:14	6.1a	11.6a	11.9ab	0.15a	0.014a	13.7a
8:18	4.9ab	11.3a	12.6ab	0.15a	0.021a	9.8ab
4:22	5.6a	12.1a	8.7b	0.14a	0.015a	9.7ab
Zingiber spectabile						
22:4	6.0a	6.2a	4.7a	0.10a	0.068abc	1.6a
20:6	6.8a	5.9a	4.6ab	0.09ab	0.082a	1.1a
16:10	3.4b	5.4a	3.1bc	0.04c	0.036c	1.1a
12:14	6.5a	7.5a	4.5abc	0.07abc	0.055abc	1.5a
8:18	6.4a	6.7a	4.4abc	0.09ab	0.073ab	1.3a
4:22	5.7a	6.0a	3.0c	0.06bc	0.044bc	1.3a
Alpinia purpurata						
22:4	6.7a	6.3b	11.2a	0.14a	-	-
20:6	10.7a	6.3b	9.0ab	0.16a	-	-
16:10	11.9a	8.9a	10.3a	0.17a	-	-
12:14	9.1a	8.0a	7.3bc	0.17a	-	-
8:18	9.7a	6.8b	5.0cd	0.14a	-	-
4:22	7.9a	6.3b	3.3d	0.11a	-	-

Means followed by the same letter in the columns do not differ by Tukey test at 5% probability.

Smaller PA/root relationships were found in *Etlingera elatior* seedlings in 20K treatments: 6Ca and 16K:10Ca, indicating increased shoot growth, which in micropropagation is a favorable feature.

To *Zingiber spectabile* there was a decrease in the production of 16K treatment leaves: 10Ca compared to the others (Table 3). The height and the ratio PA / root seedlings of this species were not affected by different relations of K:Ca.

The seedlings grown in *Zingiber spectabile* 22K relationship: 4Ca showed higher root length, whereas those conducted in medium with 4 mmol L^{-1} K and 22 mmol L^{-1} Ca fell on this characteristic. For dry weight of shoots, seedlings of 22K treatment: 4Ca were higher, while the seedlings of 16K treatment: 10Ca were lower.

As the K plays an important role in regulating the osmotic potential of plant cells and activation of various enzymes, its deficiency causes the first reduction in plant growth (MALAVOLTA et al., 1997; FAQUIN, 2005).

They had higher dry matter production of root seedlings of *Zingiber spectabile* grown in 20K treatment: 6Ca, while the 16K ratio: 10Ca resulted in lower production.

The number of leaves and dry weight of shoot did not differ among the treatments studied for *Alpinia purpurata* (Table 3). Variables that showed statistical differences were height and root length. Seedlings grown in the 16K proportions: 10Ca, 12K: 14Ca and 22K: 4Ca showed an increase in these variables compared to seedlings of other treatments. The literature shows that higher concentrations of K (25.6 mmol L^{-1}) provide better growth *in vitro* for some ornamentals (FIGUEIREDO et al, 2008; SANTOS et al, 2008).

Sousa et al. (2004), evaluating different ratios of K, Na and Ca in the initial growth acai (*Euterpe oleracea*) in nutrient solution concluded that the plants have the best results when they were cultured in the 2K relationship: 4Ca (mmol L^{-1}) regardless of the presence of on the solution. Usually the demand for K by plants is much higher than that of Ca.

The P, K, Mg and S in *Etlingera elatior* seedlings, P and S contents of *Zingiber spectabile* and Ca in *Alpinia purpurata* were not influenced by the different relations of K: Ca (Table 4).

Table 4. Levels of macronutrients (g kg^{-1}) sheets of seedlings *Etlingera elatior*, *Zingiber spectabile* and *Alpinia purpurata* with different ratios K: Ca (mmol L^{-1}).
Tabela 4. Teores de macronutrientes (g kg^{-1}) em folhas de plântulas de Etlingera elatior, Zingiber spectabile e Alpinia purpurata com diferentes relações K:Ca (mmol L^{-1}).

Relation K:Ca					
Etlingera elatior					
Relation K:Ca	P	K	Ca	Mg	S
	g kg^{-1}				
22:4	2.76a	35.32a	5.25d	2.16a	0.52a
20:6	3.23a	36.15a	7.26c	2.36a	1.02a
16:10	3.18a	35.14a	9.04b	1.79a	0.76a
12:14	2.46a	35.46a	9.73b	2.09a	0.79a
8:18	2.66a	32.52a	12.43a	1.95a	0.96a
4:22	3.30a	34.08a	13.49a	1.91a	1.09a
Zingiber spectabile					
22:4	3.1a	34.9b	4.4c	2.9a	0.6a
20:6	3.6a	35.0b	5.8c	2.7a	0.6a
16:10	2.7a	50.6a	8.0b	3.0a	0.4a
12:14	3.4a	26.3b	11.2ab	2.4ab	0.7a
8:18	3.2a	39.6b	14.6a	2.4ab	0.8a
4:22	3.3a	37.6b	10.3ab	1.9b	0.6a
Alpinia purpurata					
22:4	1.62b	25.20a	4.32a	2.98a	2.73b
20:6	3.15a	27.48a	5.67a	3.14a	2.83b
16:10	2.82a	24.12a	5.97a	2.26b	2.93b
12:14	3.01a	22.66a	4.78a	1.76b	3.17b
8:18	3.42a	23.56a	3.85a	1.70b	4.38a
4:22	2.76a	20.54b	5.05a	2.18b	4.84a

Means followed by the same letter in the columns do not differ by Tukey test at 5% probability.

The *Alpinia purpurata* seedlings 22K treatment: 4Ca had the lowest levels of P. Gunes et al. (1998) cited the synergistic effect of K in tomato (*Solanum lycopersicum*) plants in relation to P.

There was an increase in the levels of K in *Zingiber spectabile* seedlings in 16K treatment: 10Ca. To *Alpinia purpurata*, there was a decrease in K content in seedlings of treatment at lower concentrations of this nutrient in the cultivation solution 4K: 22Ca. It is noteworthy that the K, depending on the different relations of K: Ca, showed different behaviors in the three species evaluated.

Ca levels in seedlings *Etlingera elatior* and *Zingiber spectabile* varied depending on the concentrations of this nutrient in the culture medium, in that the greater the availability of Ca in the solution, the higher the absorption of the same.

For seedlings *Zingiber spectabile* and *Alpinia purpurata*, there was an increase in Mg levels in treatments with lower concentrations of Ca in culture solution. The lowest concentration of Ca in culture medium favors the absorption of Mg, probably by decreasing the existing competitive inhibition between these cations (BERGMANN, 1992).

In seedlings of *Alpinia purpurata*, an increase in S levels in 8K treatments: 18Ca and 4K: 22Ca. The same happened with this species in relation K:Mg, indicating that the low concentration of K in the culture favored the absorption of S, but this interaction is not mentioned in the literature.

4. CONCLUSIONS

It is possible to improve the growth of zingiberaceas plants during the micropropagation, changing the concentrations of K, Ca and Mg original formulation MS.

The recommend K concentrations are 22 mmol L^{-1} for *Etlingera elatior* and *Zingiber spectabile* and 16 mmol L^{-1} for *Alpinia purpurata*.

The recommend concentrations of Ca are 4 mmol L^{-1} to *Etlingera elatior* and *Zingiber spectabile* and from 8 to 10 mmol L^{-1} for *Alpinia purpurata*.

Higher concentration of Mg is required for *in vitro* culture of *Etlingera elatior,* and more studies are suggest to determine optimal concentrations.

For the species *Alpinia purpurata* and *Zingiber spectabile* are recommended the concentration of 3 mmol L^{-1} Mg in MS medium.

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